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uable investigation of the Theory of Precession and Nutation, in which he succeeded in a development, where LAPLACE, STOCKWELL, and ADAMS had failed. In this the long-period periodic planetary terms caused trouble. LAPLACE and the others failed because they sought to find the general solution, retaining the long-period periodic terms, and wishing to derive the planetary terms through ordinary quadratures. BACKLUND, on the other hand, succeeded by not separating them from the nutation terms, but by deriving them in the same way as the long-period elementary terms in his treatise "Ueber die Bewegung kleiner Planeten vom Hecubatypus."

In closing, I wish to mention some of the other honors that have been conferred upon our medallist. In addition to the award of the Gold Medal of the Royal Astronomical Society, to which reference has been made, he was honored by Cambridge University in 1904, when he was awarded its "Doctor in Science" *honoris causa*. Four other eminent scientists—namely, DAVID GILL, NORMAN LOCKYER, WILLIAM RAMSAY, and ARTHUR SCHUSTER—were given the same degree by Cambridge at this time. In 1905 the honorary Doctorate was conferred by the University of Kapstadt upon BACKLUND and G. H. DARWIN, DAVID GILL, and J. C. KAPTEYN.

THE GREAT AND THE SMALL—PRESIDENTIAL ADDRESS.

By ALEXANDER MCADIE.

Members of the Astronomical Society of the Pacific:

By a wise unwritten law of this Society, a layman is elected President every alternate year. In the present instance, the wisdom of the custom is not so readily apparent, and your President, conscious of short-comings even in the modest role of layman, tried his best to escape the honor which his fellow directors saw fit to offer. As a layman, however, it has been his rare privilege to know well many astronomers, and because of their patience and forbearance he has absorbed certain information which leads him to believe that astronomy, preeminently the science of vast dimensions, is none the less vitally concerned with aerology, a new science and one of comparatively limited distances.

The thickness of the Earth's atmosphere, compared with the diameter of the Earth, is as a sheet of tissue paper to the thickness of a good-sized book. Compared with the Sun's diameter, the ratio would be tissue paper to one hundred volumes; or, to the distance of the Sun, as tissue to one hundred times the hundred volumes; and, finally, if we compare the depth of the atmosphere with the distance to the nearest star, the ratio would be something like a sheet of paper to thirty-six hundred rows of books, each row containing a million volumes. Plainly, astrometry, compared with aerometry, is as the great to the small; and one might hastily infer that our atmosphere is a negligible quantity. Yet the greater is sometimes dependent on the less, and from astronomers themselves we gather that they have their troubles due to the Earth's atmosphere; for did not the President of the Royal Astronomical Society, speaking at the annual dinner of the Royal Meteorological Society not long ago, say, half jocularly, half in earnest, that the "ideal world of the astronomer would be a world in which no atmosphere existed and there were no science of meteorology and no meteorologists"? Undoubtedly, this would be the easiest solution of certain problems from the astronomical point of view, if it were not that astronomers, like other people, must live.

It was in California, it will be remembered, that an early attempt was made to free the astronomer from some of his troubles due to dust-laden atmosphere and the aberration of the image by non-homogeneous air strata. In the history of the Lick Observatory, we have a striking illustration of increased efficiency due in part to favorable atmospheric environment. Again, at the Mt. Wilson Solar Observatory, an institution devoted specially to the study of the one near star, our Sun, the necessity of a pure and steady atmosphere has been shown to be all-important. The latter observatory and the Smithsonian Astrophysical Observatory have, thru unusual atmospheric opportunities, virtually developed a new field of research, one as yet without a name and for which until a more appropriate name shall be given we propose "solclimatics," asking forgiveness for the violence done our mother tongue.

In this field, where research practically began with LANGLEY's work in determining the value of the solar constant and the coefficients of absorption for various radiations, checked by his observations at Mt. Whitney, such questions as the relation of seasonal abnormalities of pressure and temperature, precipitation with variation in the solar output, and, in brief, all questions relating to climate control by variation of solar output, will call for co-operative work by aero-physicist and astronomer. The former must furnish whatever data are required relating to air movement, the absorption and radiation of heat at various levels in the atmosphere, and the departures due to the presence of water vapor. Nor can the aerologist longer content himself with assumed conditions and employ formulæ and equations of limited application. He must deal with the atmosphere as it is; that is, as modern exploration is showing it to be, a non-adiabatic atmosphere and not a dry, pure, perfect gas.

At this point reference may properly be made to the units now coming into use in aerological work. In the *Monthly Weather Review* for August, 1908, there appeared a paper by MCADIE on the need of more rational units in aerology; and giving an original method of recording pressure variations in percentages or permillages of a standard atmosphere. The paper was extensively commented upon and aroused much discussion. In the *Monthly Weather Review* for March, 1909, Dr. W. KÖPPEN, Director of the Deutsche Seewarte at Hamburg, pointed out that if pressure were measured in bars or millibars, as employed by BJERKNES, SANDSTROM, and others, the advantages of the percentage system proposed by MCADIE would be realized, with the additional gain that all pressures would be expressed in dynamic units. In other words, KÖPPEN's proposal was to use, instead of sea-level pressure, the pressure normally found at a height of 348 feet, or 106 meters. This would change, then, from the former barometric standard of 29.92 inches, or 760 millimeters (at latitude 45°), which in force units would be 1,013,303 dynes, to the even 1,000,000 dynes, corresponding to reading 29.53 inches, or 750 millimeters. Dr. KÖPPEN also presented to the Aerological Congress at Monaco in April, 1909, a strong plea for the use of dynes. During 1909 and 1910 the writer urged the adoption of these units by the U. S. Weather Bureau, but without success. In the *American Journal of Science* for October, 1910, and in other publications he has shown the advantages resulting from the adoption of these units. In 1910 there was published by the Carnegie Institution the first volume of "Dynamic Meteorology and Hydrography," by the well-known investigator, V. BJERKNES and collaborators. BJERKNES significantly says:—

> "In meteorology it is common to give the barometric pressure in millimeters or inches of mercury. The millimeter division is not in the least more rational than the division into inches. Neither of them has anything to do with absolute units. The consequences of this irrationality have not yet been severely felt because the barometric records have until now served for qualitative purposes mainly."

So far as known to me, no actual use of the new units (pressure in millibars and temperature in degrees absolute centigrade) was made in the United States except by the writer, at San Francisco in the period 1909-1913.[1] In Europe, under the progressive leadership of such eminent meteorologists as KÖPPEN, SHAW, ASSMANN, DINES, GOLD, CAVE, and others, the units have come into general use. Daily and weekly weather reports give pressure in millibars.[2] On January 1, 1914, the U. S. Weather Bureau began to employ these units in a daily weather map of the northern hemisphere. The following table, devised at Blue Hill Observatory, has been found convenient and may be helpful in astronomical observatories where pressures are still read in inches and fractions thereof. Copies of these conversion tables and similar tables for converting readings in millimeters may be obtained from the Director of the Blue Hill Observatory of Harvard University. In this table the first column gives the height of the barometer, in inches, for every tenth of an inch from 29.0 to 31.0. The second column gives the corresponding pressure in millibars when 1,000 is added. The remaining columns give the pressures in millibars at intermediate heights at intervals of 0.02 inches. It is to be remembered that the base is no longer sea-level, but altitude 106 meters:—

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[1] *Scientific American Supplement*, Dec. 6, 1913.

[2] *Nature*, Oct. 16, 1913.

BASE PRESSURE 1,000,000 DYNES OR 1,000 MILLIBARS.

Pressure in millibars = 1000 +.

Barometer in inches.	.00	.02	.04	.06	.08
29.00	— 18.0	— 17.3	— 16.6	— 16.0	— 15.3
29.10	— 14.6	— 13.9	— 13.2	— 12.6	— 11.9
29.20	— 11.2	— 10.5	— 9.9	— 9.2	— 8.5
29.30	— 7.8	— 7.2	— 6.5	— 5.8	— 5.1
29.40	— 4.4	— 3.8	— 3.1	— 2.4	— 1.7
29.50	— 1.1	— 0.4	+ 0.3	+ 1.0	+ 1.7
29.60	+ 2.3	+ 3.0	+ 3.7	+ 4.4	+ 5.0
29.70	+ 5.7	+ 6.4	+ 7.1	+ 7.7	+ 8.4
29.80	+ 9.1	+ 9.8	+ 10.5	+ 11.1	+ 11.8
29.90	+ 12.5	+ 13.2	+ 13.8	+ 14.5	+ 15.2
30.00	+ 15.9	+ 16.6	+ 17.2	+ 17.9	+ 18.6
30.10	+ 19.3	+ 19.9	+ 20.6	+ 21.3	+ 22.0
30.20	+ 22.6	+ 23.3	+ 24.0	+ 24.7	+ 25.4
30.30	+ 26.0	+ 26.7	+ 27.4	+ 28.1	+ 28.7
30.40	+ 29.4	+ 30.1	+ 30.8	+ 31.5	+ 32.1
30.50	+ 32.8	+ 33.5	+ 34.2	+ 34.8	+ 35.5
30.60	+ 36.2	+ 36.9	+ 37.5	+ 38.2	+ 38.9
30.70	+ 39.6	+ 40.3	+ 40.9	+ 41.6	+ 42.3
30.80	+ 43.0	+ 43.6	+ 44.3	+ 45.0	+ 45.7
30.90	+ 46.4	+ 47.0	+ 47.7	+ 48.4	+ 49.1
31.00	+ 49.7	+ 50.4	+ 51.1	+ 51.8	+ 52.4

Example: Barometer reading 29.62 inches, convert to millibars. Tabular correction for 29.60 + .02 is + 3.0. Pressure in millibars is 1000 + 3.0 = 1003.0.

Beginning with the familiar equation connecting pressure, P, volume, V, temperature, T, and gas constant, R,—

$$PV = RT,$$

the height of the so-called homogeneous atmosphere,—that is, the thickness of the stratum which our entire atmosphere would form if compressed to a uniform density equal to the average density at the base level (106 meters above sea) and at temperature zero centigrade ($= 273^\circ$ Abs.),—can be found thus, in meters:—

$$\frac{13.596 \times 0.750}{0.001293} = 7886;$$

the three numerical factors being, in order, the density of mercury, the pressure reading, and the specific weight of air. We may call the value approximately 8,000 meters. The gas constant *R* is obtained by dividing by 273. If pressures are given in millibars, the value of *R* is 2.87×10^7. But these values are for dry air and need further correction. The volume of the atmosphere is approximately $4{,}080 \times 10^{15}$ cubic meters; or, since a cubic meter of dry air at 273° A. and standard gravity weighs 1.293 kilograms, the weight of the atmosphere in round numbers is $5{,}200 \times 10^{15}$ kgs. This is about 1/1,125,000 of the Earth's mass.

If we determine the approximate height of the *sensible* atmosphere by the disappearance of the twilight arch (18° below the horizon) we have Earth's radius multiplied by the secant of 9°, less 1, or $h = R\ (1.0125 - 1) = 0.0125 \times 6{,}370{,}191$ meters $= 79{,}627$ meters. This must be corrected for refraction, and the final value would be about 64,000 meters, or eight times the depth of the homogeneous atmosphere. As we have already said, the depth of the atmosphere compared with any astronomical dimension is no more than a leaf of thinnest paper to miles of books. Still the instruments of the astronomer are emplaced in this paper. For the most part, they are at the very bottom of the atmosphere. True, in some States, as in California and Arizona, instruments are used at high levels. At Mt. Wilson and Pasadena comparative work can be done at levels of 1,493 dynamic meters and 247 dynamic meters, respectively; in other words, thru a range of one fifth of the effective atmosphere. And it is feasible to work an appreciable part of the year at elevations as high as 4,500 dynamic meters. The summit of Mt. Whitney is at 4,329 dynamic meters, or 4,419 meters above sea-level, where the pressure is but 0.6 that at the basal plane. ST. JOHN of Mt. Wilson has shown that there are several spectrum lines which are displaced in measurable degree by a difference of pressure of two tenths of an atmosphere. The point is referred to, only to show that the atmosphere cannot be disregarded in ultimate determinations of wave-lengths, frequencies of vibration, and standards of length.

The most important outcome of recent exploration of the air by kites and sounding balloons is the establishment of the two great layers which are best known by the names troposphere and stratosphere. Theoretically, when dry air is lifted to a level where the pressure is reduced one-half, there should be a cooling of 50° C. In fact, and especially near mountain peaks, very different results are found. But even the adiabatic rate does not hold. This we shall return to later.

Numerous records of soundings have been published by the International Commission for Scientific Aerostation. We give one of the latest records made at the observatory at Uccle, Belgium, June 9, 1911, during pleasant weather. A height of 31,780 d. meters (32,430 meters) was reached. The lowest temperature was given by one thermometer (Hergesell) as 212° A. (—61° C) at 13,040 meters, while the balloon was rising, or 213° A. by the other thermometer (Kleinschmidt) at 12,600 meters, while the balloon was descending.

The following skeleton table may be interesting:—

Time	Pressure		Elevation	Temperature	Gradient	R. H.
	mb	mm	Met.	Abs.		
7:00	1,001	751	100	290°	...	81
7:05 (?)	900	675	1,000	287	...	..
....	797	598	2,000	281	.056	..
....	705	529	3,000	275	.066	51
7:18	621	466	4,000	269	.042	34
7:20 (?)	547	410	5,000	264	.069	..
....	479	359	6,000	251	.086	30
7:34	313	235	9,000	234	.084	30
7:38	271	203	10,900	222	.065	..
7:44	199	149	12,000	216	.039	29
7:47:04[1]	168	126	13,040	213	.021	29
7:48	160	120	13,340	213	—.007	29
7:52	129	97	14,650	218	—.031	30
7:56	103	78	16,050	223	—.07	29
8:02	72	54	18,370	218	.01	29
8:12	36	27	22,720	222	.00	29
8:32	8	6	32,430	234	...	29

The adiabatic gradient generally employed is 9.87° C. per kilometer. For 5.5 kilometers, therefore, the fall in temperature would be about 54°. But the rate holds only for small changes; and, as DINES[2] has pointed out, the formula "in fact is only true for the supposed case of convective equilibrium which, so far as dry air is concerned, never exists in practice for any large change of height." He gives the following departures for different heights, assuming average conditions:—

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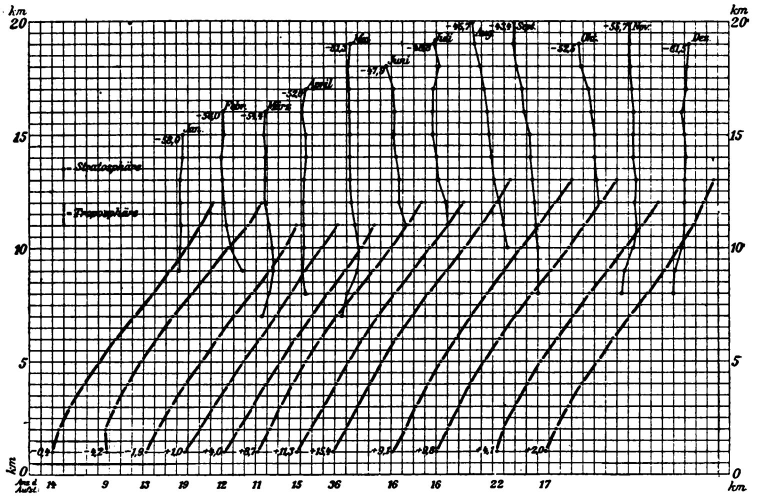
[1] Beginning of inversion.

[2] *Quar. Jour. R. Met. Soc.*, July, 1913, Vol. XXXIX, No. 167, page 187.

1km	0°.3 C	9km	7°.6 C
2	0 .6	10	9 .7
3	1 .0	11	11 .3
4	1 .8	12	13 .9
5	2 .6	13	16 .7
6	3 .5	14	19 .8
7	4 .5	15	25 .0
8	6 .0		

Temperature, then, does not fall as rapidly as the law requires and the pressure at a given level is greater than that



Mean. Temperature for Each Month, with Stratosphere and Troposphere Limits.

From G. Nadler, in *Beiträge zur Physik der freien Atmosphäre.*

given by formula. Bigelow[1] shows that the gas coefficient *R*, while a constant in the adiabatic system, is a variable in the non-adiabatic system. In other words, the specific heat is a variable in non-adiabatic air. This means that no account is taken of circulation or of radiation of heat. He very properly says "that the gravity, pressure, and circulation terms, as computed from the observations in cyclones, anti-cyclones, and in the general circulation, do not conform; and all the efforts of meteorologists to make them do so have been failures or fictitious and improper solutions."

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[1] *American Journal of Science*, Vol. XXXIV, December, 1912.

From the results of nearly two hundred soundings made during 1906-08, NADLER has summarized the mean temperature at various levels for each month and also the average limits of the troposphere and stratosphere. (See diagram.[1])

What precedes shows that a ray of light traversing the atmosphere does not come thru a homogeneous medium nor thru one of uniformly decreasing density. This must materially affect the values of the coefficients of refraction as ordinarily given. As to measuring the heights of mountains by vertical angles (theodolites), it is interesting to know that other methods presumably less accurate have given truer heights. Thus, in measuring the heights of Mts. Whitney Shasta, and Rainier, the results obtained by the writer, using atmospheric pressure methods, were nearer the true elevations than those obtained with theodolites by the engineers. Again, in measuring the high peaks of Asia (to which Professor E. C. PICKERING has called my attention) the British geodesists found that all angles of elevation to high peaks, measured from the plains of India and from the outer hills, were too large. This is strikingly shown in the case of Mt. Everest, where all measurements from low-lying stations make the mountain over 30,000 feet, while all measurements from the high levels make the mountain less than 30,000 feet. Refraction is the cause of the difference, and coefficients suitable for low levels are not accurate for high air work. According to BURRAD and HAYDEN, refraction is greatest in the morning and evening and least in the middle of the day. It is different in summer from winter.

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[1] The figures beneath the diagram (*Ans. d.* and *Aufst.*) indicate the number of soundings upon which each monthly curve is based. The figures at the right and left express the altitude in kilometers, and those on the diagram itself, the temperatures in degrees C. For example, 15 sounding balloon ascensions in July gave average temperature of + 11°.3 C. at altitude one kilometer. The temperature decreased up to altitude 12 kilometers, and then remained almost constant, or increased slightly to altitude 19 kilometers, temperature — 48°.8 C.

Tucker, in *Lick Observatory Bulletin,* No. 231, has discussed the diurnal variation in the refraction at Mt. Hamilton, using observations for a period of nearly twenty years. He finds a slight but distinct difference between the refraction effect in the daylight and night hours that does not depend upon the pressure, temperature, or change of temperature during the observing hours. He suggests that the physical explanation may lie in the rapid changes in the surface strata as compared with slower changes in higher levels near the time of sunrise and sunset, so that the readings of the thermometers in the air strata near the Earth's surface are not representative of the temperatures in overlying strata. Evidently soundings of the atmosphere near Mt. Hamilton might show frequent and marked inversions of temperature.

Again, there are many questions connected with the transparency of the air. For example, the successful use of the photo-electric cell, which promises so much in photometric measurements, must be affected by any rapid variations in air transparency. Can the aero-physicist be of service to the astro-physicist in this rapidly developing field?

Meteorology had its beginning under the sheltering domes of astronomy. Altho men live in the air, they seem to have been interested more in the motions of the stars than in the movements of the medium in which they lived. After many years of waiting came the Burgomaster of Magdeburg, with his air-pump; then Galileo, inventor of thermometer as well as telescope; and after him Torricelli, with the barometer. What instruments are we still waiting for that shall help us to a better understanding of this envelope of gases and water-vapor, relatively small in itself, but meaning so much to the development of astronomy?

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